

# **NATIONAL BUREAU OF STANDARDS REPORT**

6698

on

**Interlaboratory Intercomparisons**

of

**40-Watt T12 Cool White Fluorescent Lamps**

by

**Velma I. Burns**

**Photometry and Colorimetry Section**

**Optics and Metrology Division**



**U. S. DEPARTMENT OF COMMERCE  
NATIONAL BUREAU OF STANDARDS**

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NBS PROJECT

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U. S. DEPARTMENT OF COMMERCE  
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Interlaboratory Intercomparisons  
of  
40-Watt T12 Cool White Fluorescent Lamps

Abstract

A group of six 40-watt T12 cool white fluorescent lamps were measured by each of eight laboratories. The luminous flux, current, lamp voltage, lamp watts, and the x and y chromaticity coordinates were measured. The line voltage was held constant at 236 volts across the lamps in series with a reactor having 439 ohms and 7-8% power factor. The results of the measurements made by the individual laboratories and an analysis of the results are given in this report.

I. Introduction

This intercomparison was undertaken to determine the uniformity of measurements on 40-watt T12 cool white fluorescent lamps made at the participating laboratories. The laboratories participating and the order of reading are as follows:

- I. General Electric
- II. Electrical Testing Laboratories
- III. Westinghouse
- IV. Duro Test
- V. National Bureau of Standards
- VI. Sylvania
- VII. Champion
- VIII. Interlectric

The order in which the laboratories made their measurements was chosen to reduce shipment of the lamps as much as possible. Each laboratory followed its own customary procedure in making the measurements. Measurements in each laboratory were obtained by holding the line voltage at 236 volts. A reference ballast adjusted to 439 ohms and 7 to 8% power factor was used. The supply was connected to the marked pins.

During the intercomparisons the lamp numbers became almost illegible and the lamps were renumbered by one of the laboratories. Each lamp thus has two numbers and these are listed below.

Old number	New number
1	CW-1
4	CW-2
6	CW-3
7	CW-4
8	CW-5
10	CW-6

The new numbers are used in this report.





## II. Results of Measurements

The results reported are given in Tables 1 through 7. The averages reported for each lamp and for each laboratory are given. The difference between the average for each laboratory and the average of all laboratories for all lamps is also given in the tables.

Table 1

### Luminous Flux in Lumens

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	2623	2510	2556	2528	2495	2490	2510	2465	2522.1
CW-2	2636	2525	2559	2556	2504	2502	2538	2470	2536.2
CW-3	2614	2495	2554	2526	2495	2528	2498	2470	2522.5
CW-4	2600	2490	2549	2520	2495	2494	2500	2460	2513.5
CW-5	2625	2510	2575	2540	2509	2502	2508	2500	2533.6
CW-6	2573	2490	2533	2520	2471	2478	2492	2475	2504.0
Ave.	2611.8	2503.3	2554.3	2531.7	2494.8	2499.0	2507.7	2473.3	2522.0
$\Delta$	+89.8	-18.7	+32.3	+9.7	-27.2	-23.0	-14.3	-48.7	
% $\Delta$	+3.56%	-.74%	+1.28%	+.38%	-1.08%	-.91%	-.57%	-1.93%	

Table 2

### Current in Amperes

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	.433	.432	.432	.433	.425	.436	.433	.435	.4324
CW-2	.433	.430	.430	.432	.423	.433	.432	.430	.4304
CW-3	.434	.431	.431	.434	.424	.432	.434	.435	.4319
CW-4	.435	.433	.432	.435	.424	.436	.435	.435	.4331
CW-5	.435	.432	.431	.434	.426	.434	.434	.430	.4320
CW-6	.435	.433	.431	.434	.426	.434	.435	.435	.4329
Ave.	.4342	.4318	.4312	.4337	.4247	.4342	.4338	.4333	.4321
$\Delta$	+.0021	-.0003	-.0009	+.0016	-.0074	+.0021	+.0017	+.0012	
% $\Delta$	+.48%	-.07%	-.21%	+.37%	-1.74%	+.48%	+.39%	+.28%	





Table 3

Lamp Volts

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	99.7	99.5	100.0	99.8	100	98.0	101.1	98	99.51
CW-2	99.7	99.5	100.9	101.5	100	99.0	102.1	98	100.09
CW-3	99.7	99.0	100.7	101.4	100	100.0	99.8	97	99.70
CW-4	98.8	98.5	96.6	99.4	99	97.5	100.0	98	98.48
CW-5	98.7	98.5	100.6	99.6	100	99.0	101.0	99	99.55
CW-6	<u>99.3</u>	<u>98.5</u>	<u>101.9</u>	<u>100.1</u>	<u>100</u>	<u>98.5</u>	<u>100.7</u>	<u>100</u>	<u>99.88</u>
Ave.	99.32	98.92	100.12	100.30	99.83	98.67	100.78	98.33	99.53
$\Delta$	-.21	-.61	+.59	+.77	+.30	-.86	+1.25	-1.20	
% $\Delta$	-.21%	-.62%	+.59%	+.77%	+.30%	-.87%	+1.24%	-1.22%	

Table 4

Watts

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	39.4	39.1	39.2	39.2	38.6	38.9	39.6	40	39.25
CW-2	39.3	39.1	39.5	39.2	38.7	39.0	39.7	40	39.31
CW-3	39.5	39.1	39.6	39.5	38.7	39.3	39.1	39	39.22
CW-4	39.2	38.9	39.1	39.2	38.5	39.7	39.3	40	39.24
CW-5	39.2	38.8	39.5	39.1	38.6	39.1	39.6	40	39.24
CW-6	<u>39.4</u>	<u>39.2</u>	<u>40.1</u>	<u>39.4</u>	<u>38.9</u>	<u>39.2</u>	<u>39.5</u>	<u>41</u>	<u>39.59</u>
Ave.	39.33	39.03	39.50	39.27	38.67	39.20	39.47	40.00	39.31
$\Delta$	+.02	-.28	+.19	-.04	-.64	-.11	+.16	+.69	
% $\Delta$	+.05%	-.72%	+.48%	-.10%	-1.66%	-.28%	+.41%	+1.72%	

Table 5

Lumens per Watt

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	66.5	64.1	65.2	64.5	64.6	64.0	63.4	61.6	64.24
CW-2	67.1	64.1	64.9	65.2	64.7	64.2	63.9	61.7	64.54
CW-3	66.2	63.8	64.5	64.0	64.5	64.3	63.8	63.3	64.30
CW-4	66.4	64.0	65.2	64.3	64.8	62.8	63.6	61.5	64.08
CW-5	66.9	64.7	65.3	65.0	65.0	64.0	63.4	62.5	64.60
CW-6	<u>65.3</u>	<u>63.5</u>	<u>63.7</u>	<u>64.0</u>	<u>63.5</u>	<u>63.2</u>	<u>63.0</u>	<u>60.4</u>	<u>63.32</u>
Ave.	66.40	64.12	64.80	64.50	64.52	63.75	63.52	61.83	64.18
$\Delta$	+2.22	-.06	+.62	+.32	+.34	-.43	-.66	-2.35	
% $\Delta$	+3.34%	-.09%	+.96%	+.50%	+.53%	-.67%	-1.04%	-3.80%	



Table 6

x Coordinate

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	.3692	.371	.370	.3714	.368	.371	.372	.372	.3706
CW-2	.3691	.370	.370	.3710	.369	.370	.371	.371	.3701
CW-3	.3690	.371	.370	.3692	.368	.370	.371	.372	.3700
CW-4	.3685	.371	.370	.3683	.368	.371	.371	.372	.3700
CW-5	.3694	.370	.370	.3698	.368	.370	.371	.371	.3699
CW-6	<u>.3695</u>	<u>.370</u>	<u>.370</u>	<u>.3702</u>	<u>.369</u>	<u>.371</u>	<u>.371</u>	<u>.373</u>	<u>.3705</u>
Ave.	.3691	.3705	.3700	.3700	.3683	.3705	.3712	.3718	.3702
$\Delta$	-.0011	+.0003	-.0002	-.0002	-.0019	+.0003	+.0010	+.0016	
% $\Delta$	-.30%	-.08%	-.05%	-.05%	-.52%	+.08%	+.27%	+.43%	

Table 7

y Coordinate

<u>Lamp No.</u>	<u>G.E.</u>	<u>ETL</u>	<u>West</u>	<u>Duro T</u>	<u>NBS</u>	<u>Syl</u>	<u>Champ</u>	<u>Interl</u>	<u>Ave.</u>
CW-1	.3737	.374	.373	.3733	.371	.376	.376	.377	.3742
CW-2	.3729	.373	.372	.3730	.371	.372	.373	.376	.3729
CW-3	.3736	.374	.372	.3738	.371	.373	.375	.376	.3736
CW-4	.3735	.373	.372	.3734	.371	.373	.373	.377	.3732
CW-5	.3730	.373	.372	.3731	.371	.374	.375	.377	.3735
CW-6	<u>.3752</u>	<u>.373</u>	<u>.372</u>	<u>.3741</u>	<u>.371</u>	<u>.373</u>	<u>.373</u>	<u>.377</u>	<u>.3735</u>
Ave.	.3736	.3733	.3722	.3734	.3710	.3735	.3742	.3767	.3735
$\Delta$	+.0001	-.0002	-.0013	-.0001	-.0025	.0000	+.0007	+.0032	
% $\Delta$	+.03%	-.05%	-.35%	-.03%	-.67%	0%	+.19%	+.85%	

III. Analysis of the Results

An analysis of the results of the measurements has been made following a modification of the method described by W. J. Youden<sup>(1),(2),(3)</sup>. This is also

- 
- (1) Graphical Diagnosis of Interlaboratory Test Results, Industrial Quality Control. Vol. XV, No. 11, May 1959.
  - (2) Product Specifications and Test Procedures, Industrial and Engineering Chemistry, Vol. 50, page 91A, October 1958.
  - (3) Circumstances Alter the Cases, Industrial and Engineering Chemistry, Vol. 50, page 77A, December 1958.
-





a modification of the method used in NBS Report 6605, "Interlaboratory Inter-comparisons of 32-Watt T10 Cool-White Circline Lamps". The method is as follows:

Let  $x_i$  represent the average lumen value for the odd numbered lamps reported by an individual laboratory and let  $y_i$  represent the average lumen value for the even numbered lamps reported by an individual laboratory. Then  $x_i$  was used as the x coordinate and  $y_i$  was used for the y coordinate to plot a point which represents each laboratory on a graph (see figure 1). The point for each laboratory is designated by a letter.

General Electric	G
Electrical Testing Laboratory	E
Westinghouse	W
Duro Test	D
National Bureau of Standards	N
Sylvania	S
Champion	C
Interlectric	I

The point which represents the averages for the two groups of lamps for all laboratories ( $\bar{x}, \bar{y}$ ) is designated by a solid circle on the graph. A line has been drawn through ( $\bar{x}, \bar{y}$ ) at  $45^\circ$  to the axes.

If only random errors were present in the reported values the eight points ( $x_i, y_i$ ) would cluster around the average point ( $\bar{x}, \bar{y}$ ) in an approximately circular pattern. On the other hand if  $x_i$  differs from  $\bar{x}$  by L lumens and if  $y_i$  differs from  $\bar{y}$  by the same number (L) lumens the point representing the individual laboratory will lie precisely on the  $45^\circ$  line. The distance from ( $\bar{x}, \bar{y}$ ) to ( $x_i, y_i$ ) along the  $45^\circ$  line is proportional to the laboratory bias.

Since in the reported values for lumens both random errors and laboratory bias exist, the points form an elliptical pattern with the  $45^\circ$  line as the major axis. When the biases are relatively large, as they are in this case, the ellipse is elongated and the points lie more or less closely along the line. When the random errors are large the points lie away from the  $45^\circ$  line, the larger the random errors the further from the line, and the ellipse becomes more circular in shape.

Lines from the points representing each laboratory have been drawn perpendicular to the  $45^\circ$  line. The distance along the  $45^\circ$  line from the average point ( $\bar{x}, \bar{y}$ ) to the foot of the perpendicular line when divided by  $\sqrt{2}$  is an estimate of the relative laboratory bias, and the length of the perpendicular line divided by  $\sqrt{2}$  is an estimate of the precision of the laboratory. It may be shown that these distances agree with the value obtained by a classical method of analysis of variance when  $x_i$  and  $y_i$  are treated as pairs of duplicate measurements. (3)

The results reported for current, lamp volts, watts, lumens per watt, and for the x and y chromaticity coordinates have been treated in the same way.





The graphs are shown in figures 2, 3, 4, 5, 6, and 7.

Figure 8 is a graph, included at the suggestion of one of the participating laboratories. It shows, plotted along the y axis, the range of lumen values for the group of six lamps by each laboratory and also the range in the averages for the lamps. Along the x axis is plotted the difference between the average reported by each laboratory for the six lamps and the average reported by all the laboratories (shown as %  $\Delta$  in Table 1.)



Figure 1

Lumens

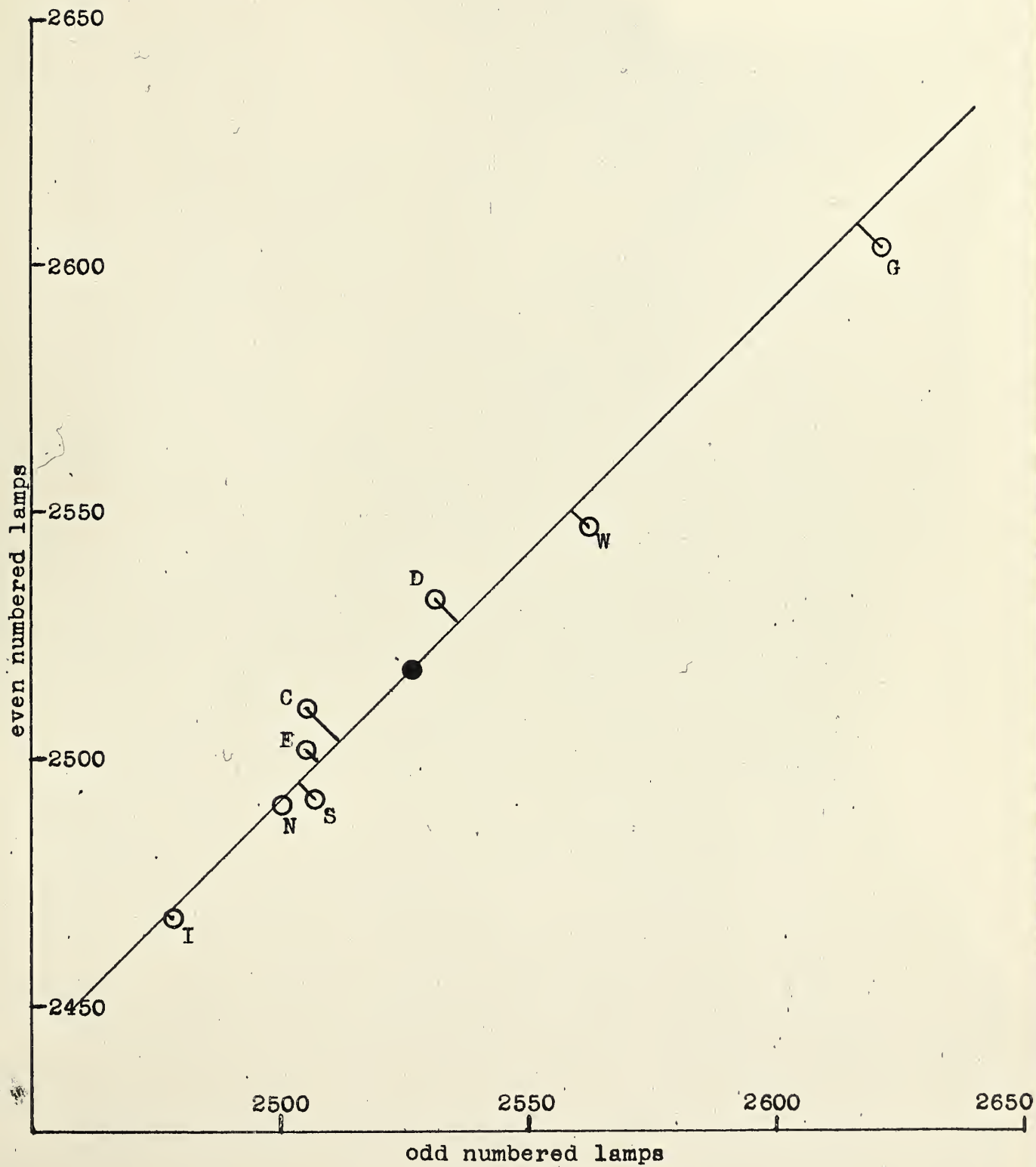




Figure 2

Amperes

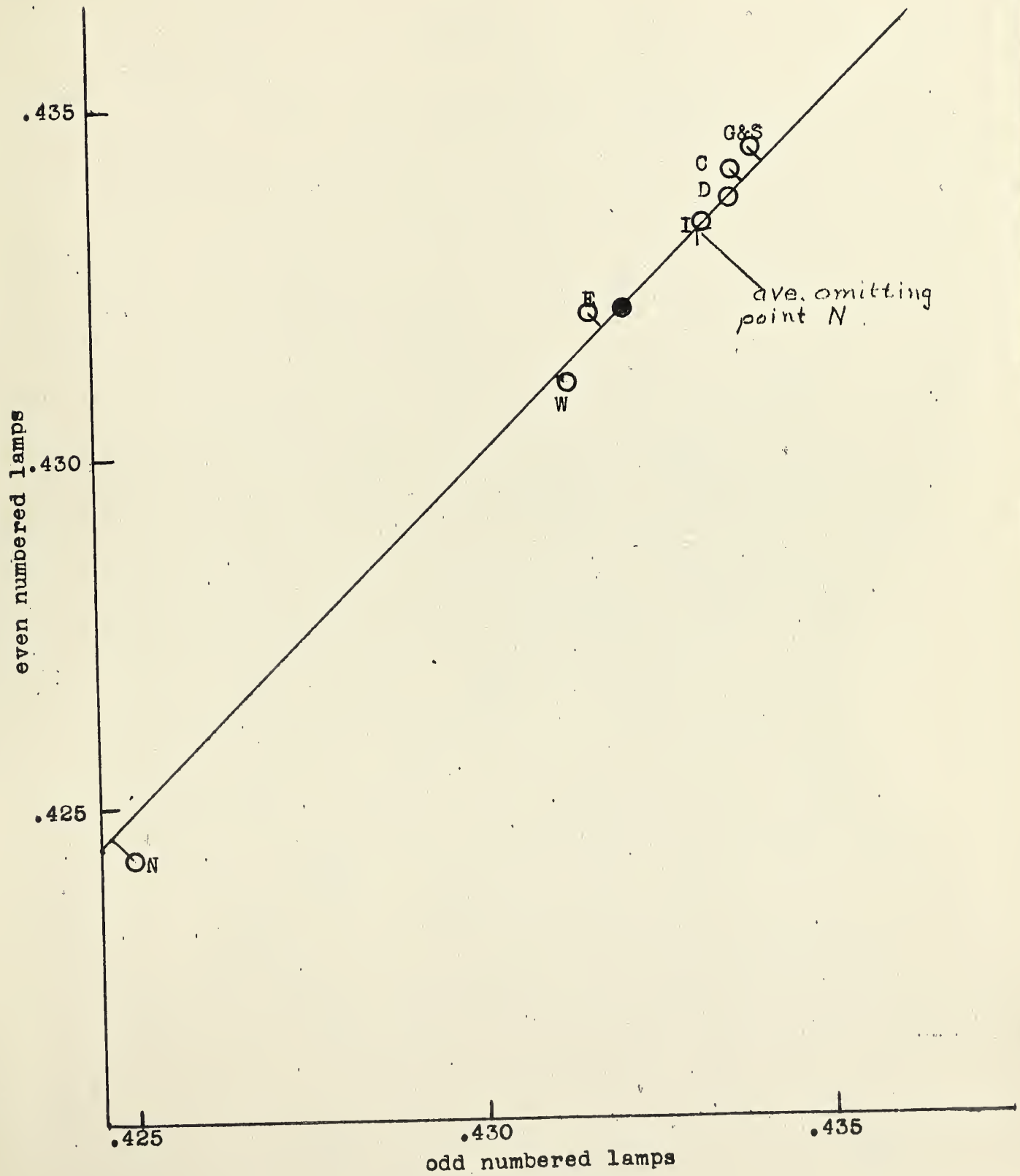






Figure 3  
Lamp Volts

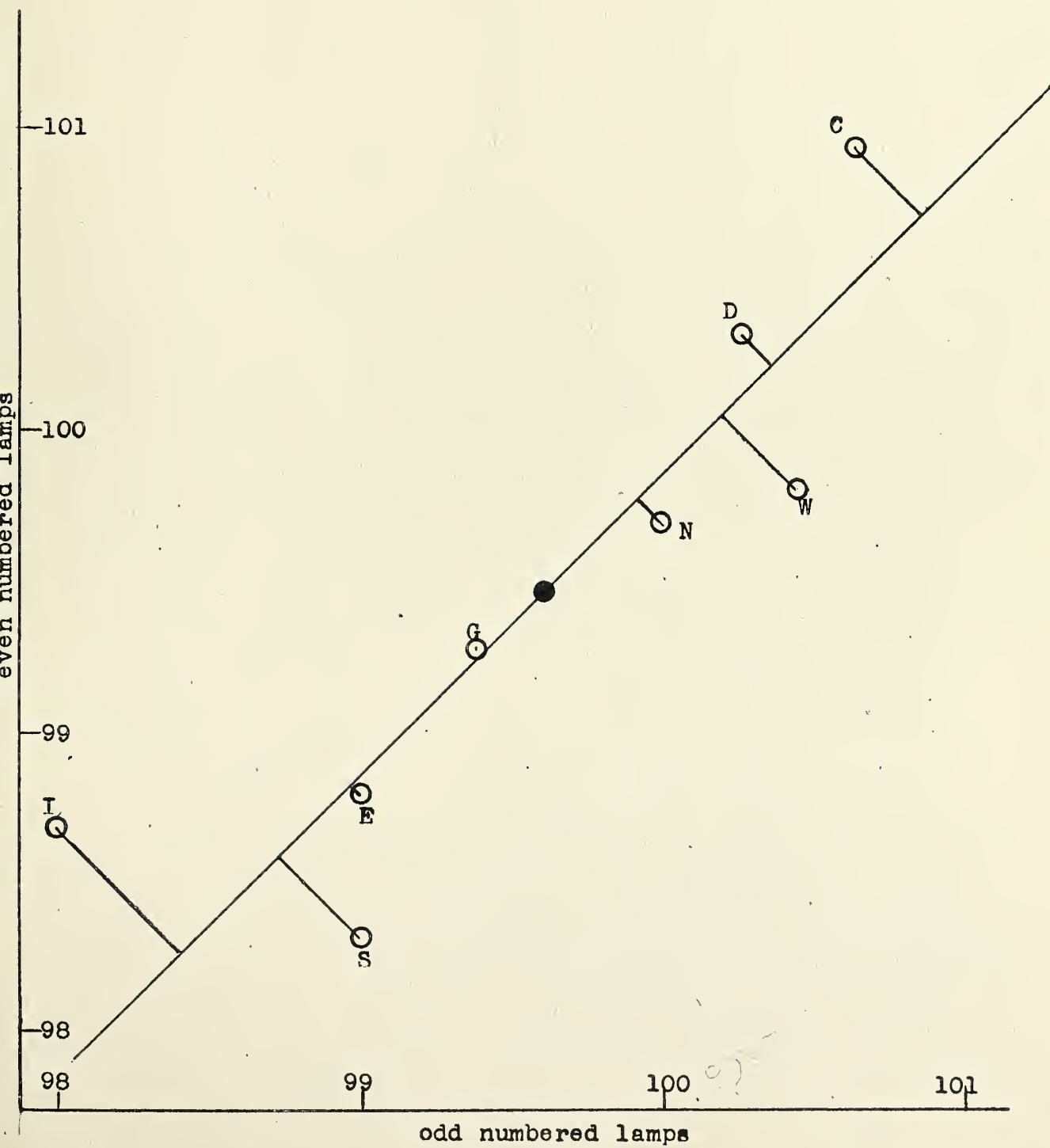
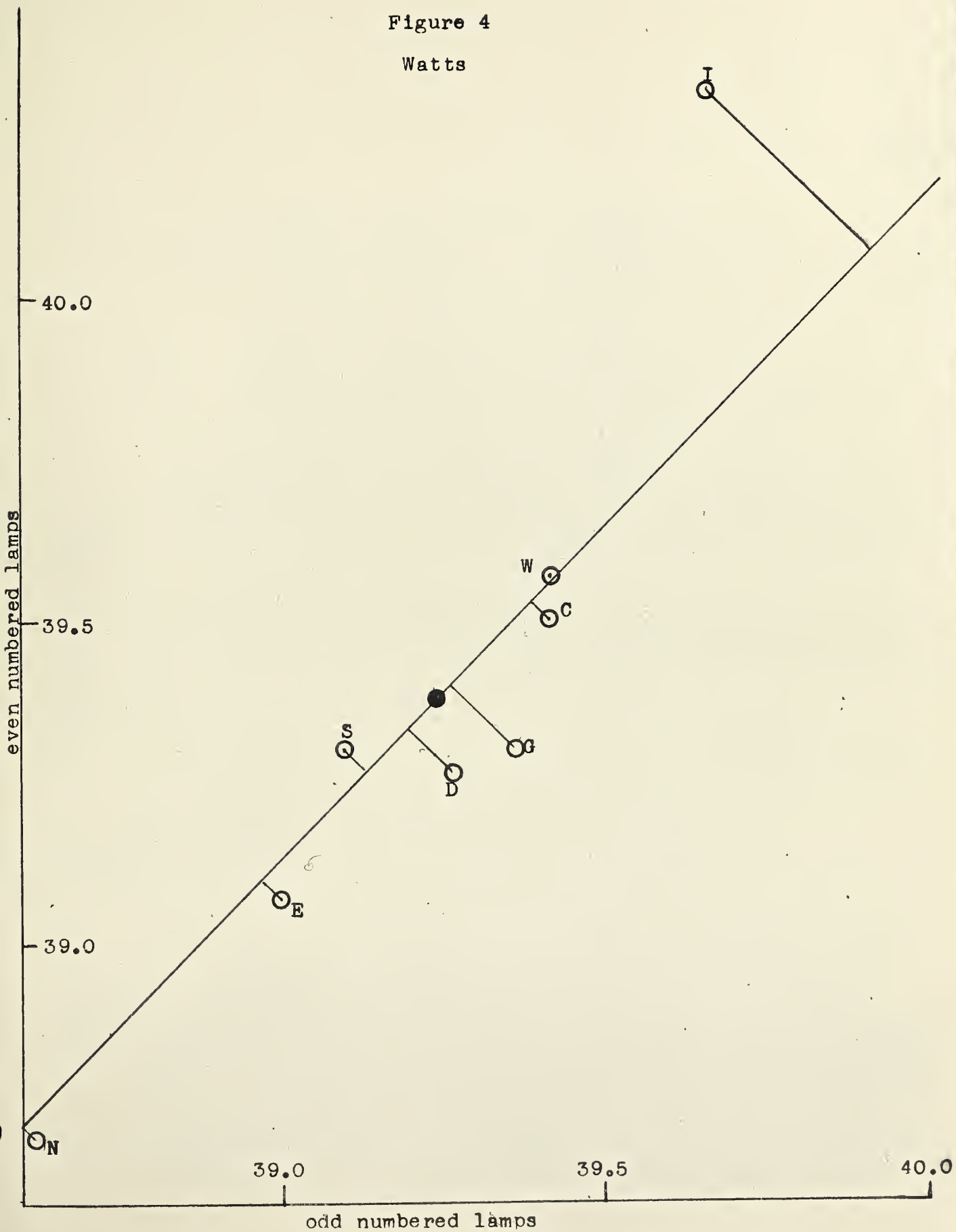




Figure 4

Watts

even numbered lamps



odd numbered lamps



Figure 5  
Lumens per Watt

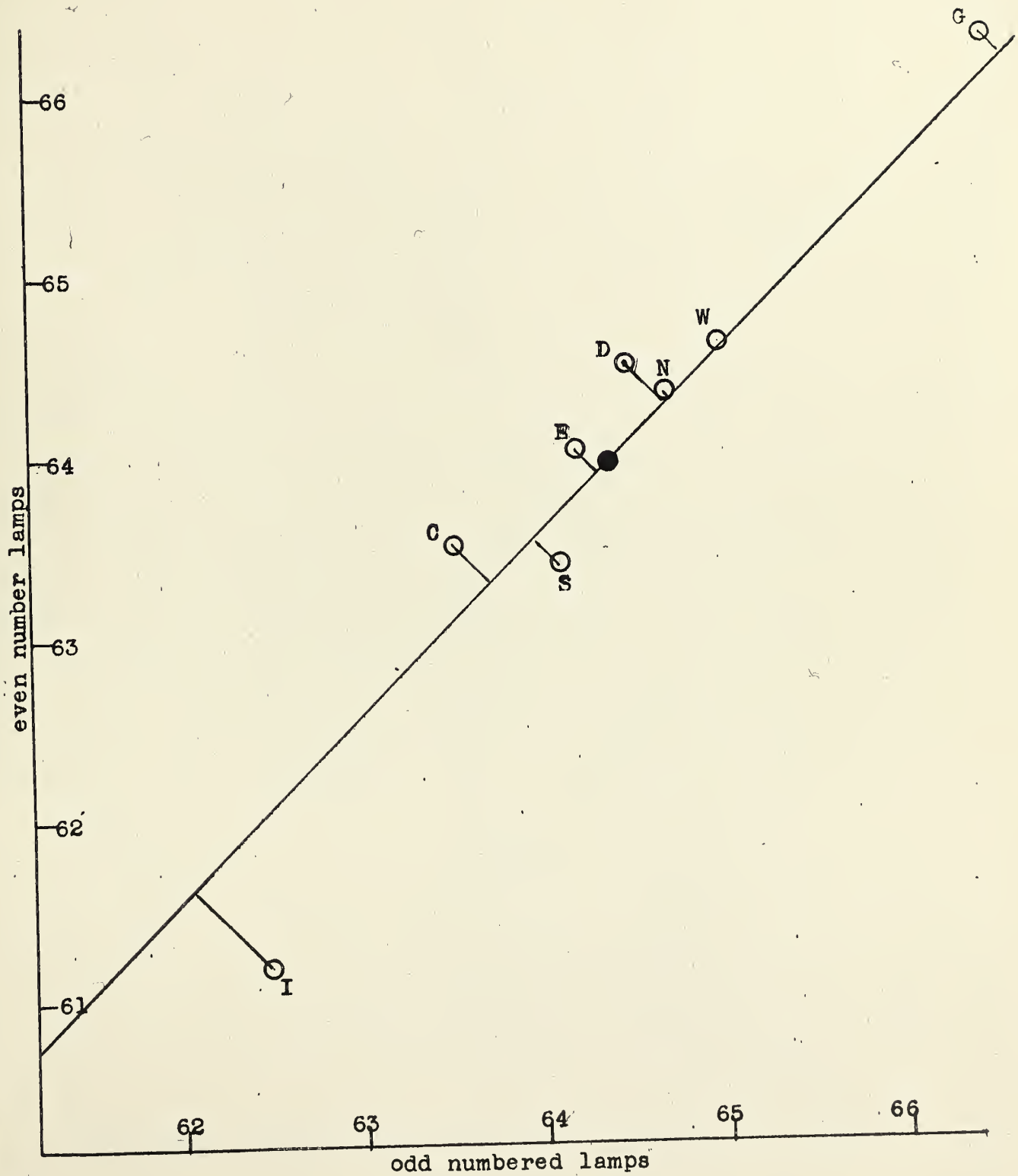






Figure 6  
x Coordinate

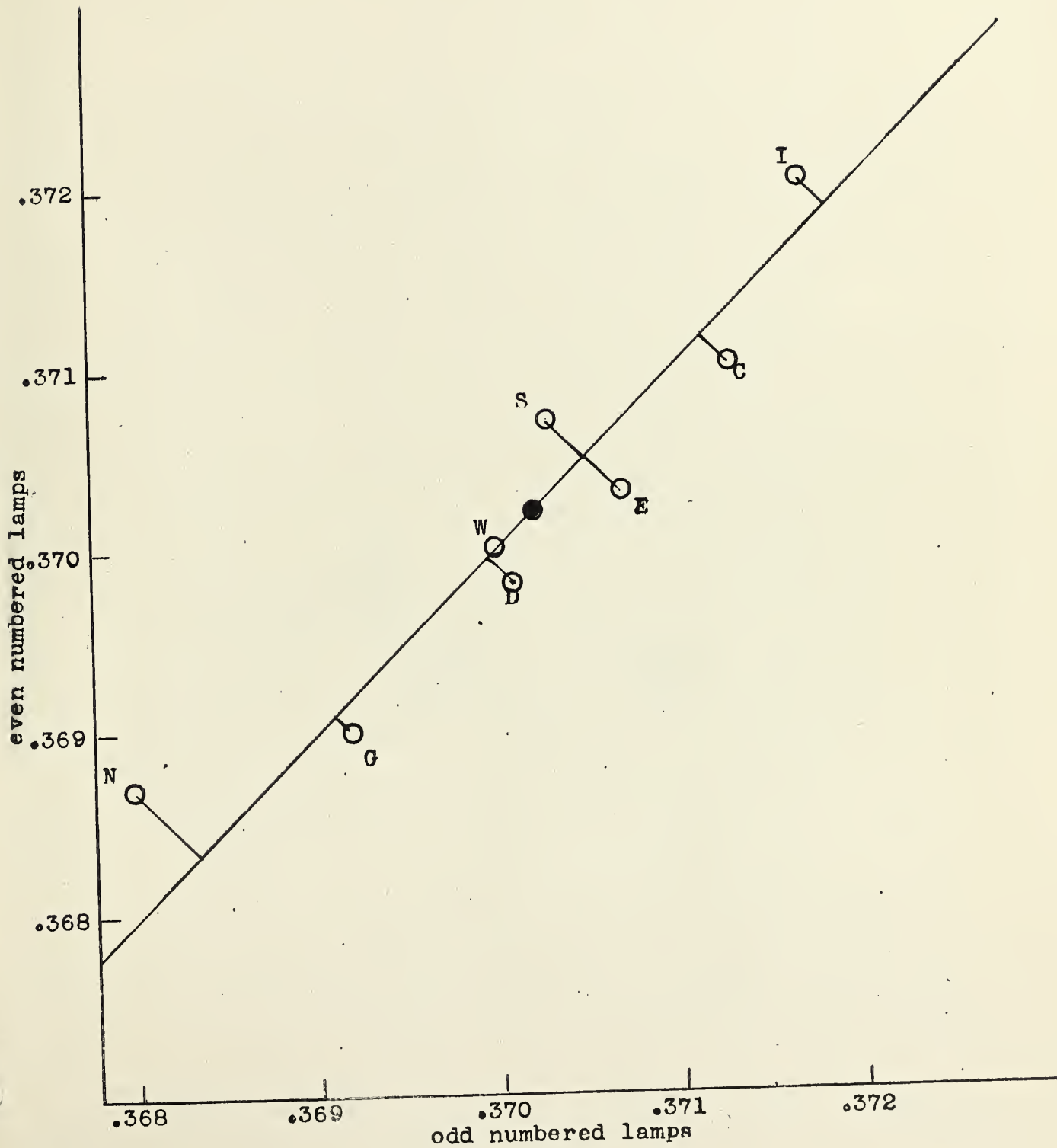




Figure 7  
y Coordinate

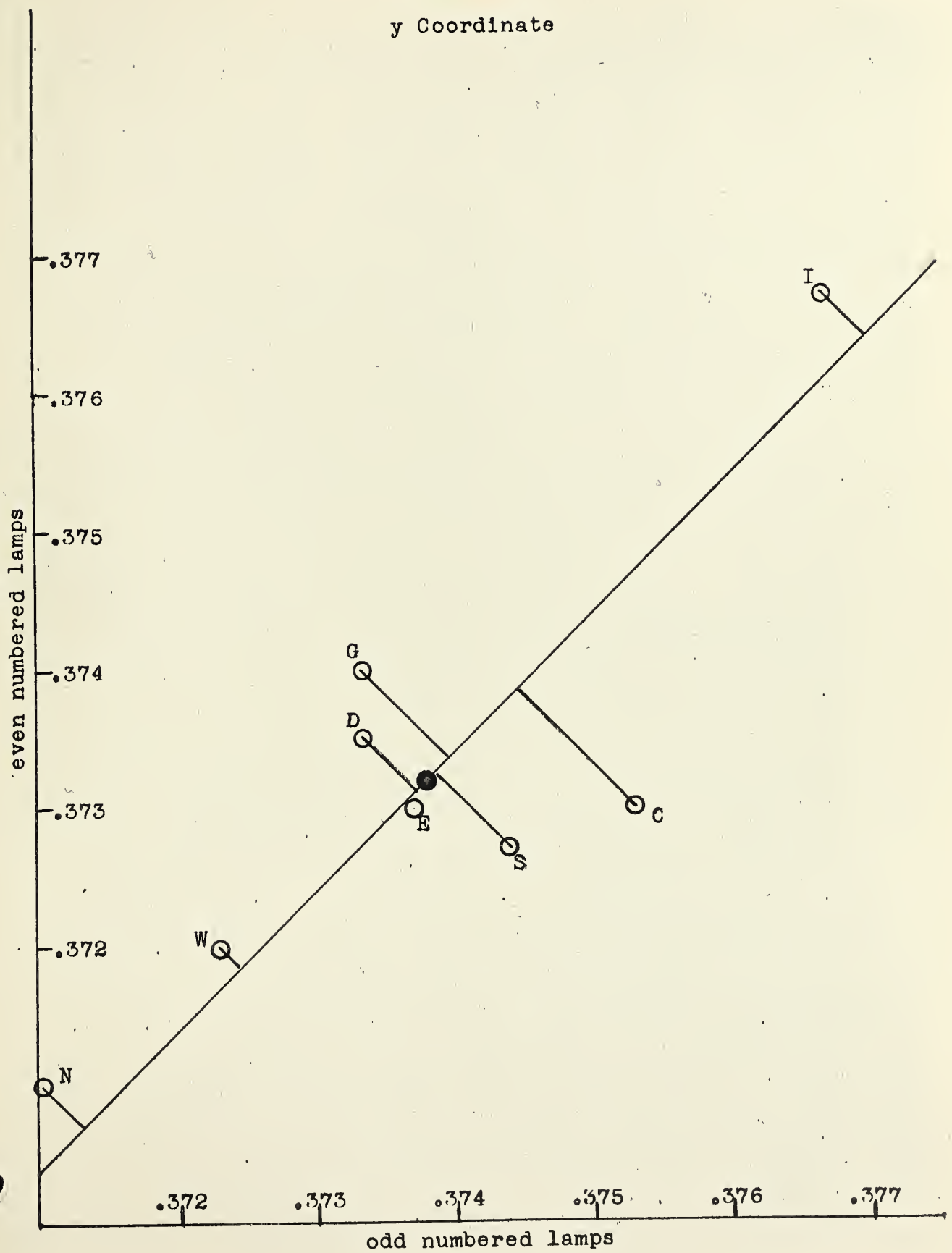


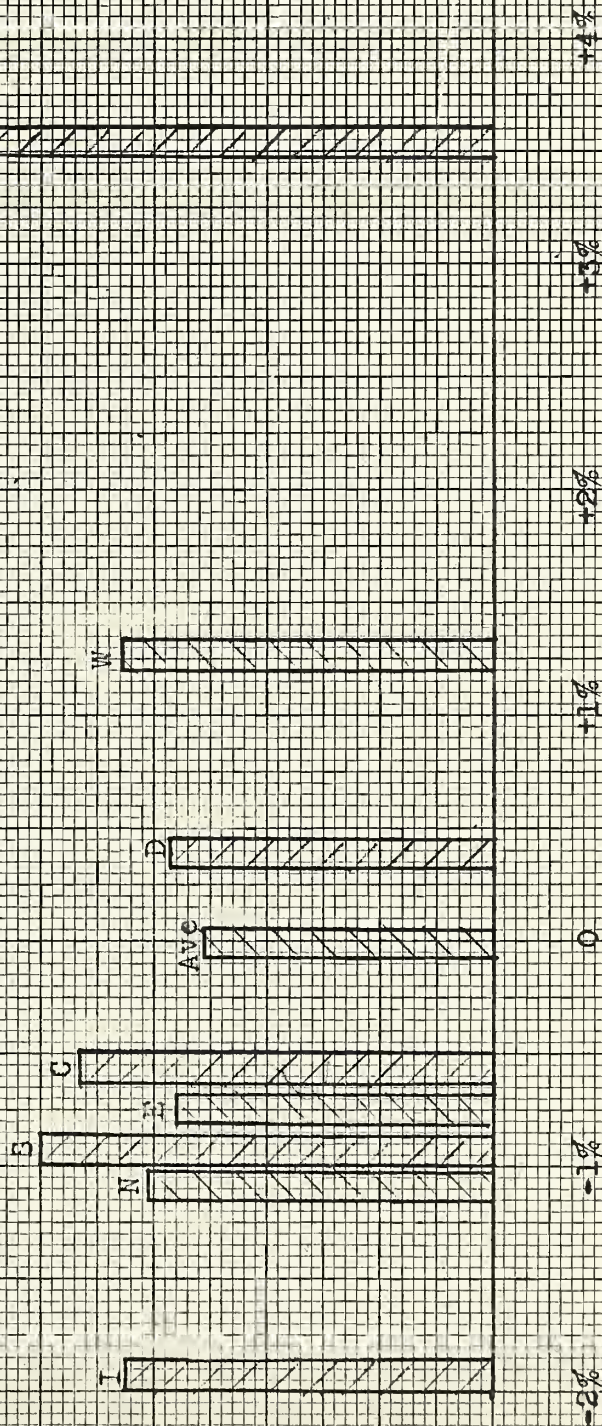




Figure 8

Lumens

% Range of Individual Readings



% difference from all laboratories average





U.S. DEPARTMENT OF COMMERCE

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• Office of Weights and Measures.

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